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ICS-4 Review

The Role of Waves in Substorm Onsets

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Introduction

It has been hypothesized that a near-Earth ($x \cong -10\ R_E$) neutral line is formed during substorm onsets. The magnetic field line reconnection at the neutral line is believed to be initiated by instabilities. A considerable number of different instability/wave mode generation mechanisms were discussed at this Conference. An outline of the mechanisms is give in Table 1. In the Table we use some abbreviations. The number 5 is the paper number 5 in Section 3 in the ICS-4 abstract book. A hyphenated number, e.g., 2-13 is paper 13 from Section 2. P8 is poster paper number 8 in Section 3.

Table 1. Role of Waves in Substorms Onsets

Ballooning	Tearing	Interchange	Drift Kink
5,7, 16, 2-13	16, 17, P8	5	4, P4, 2-12
Helicon	Alfvénic	LHD	Cross-field
17	P15	4, P4, P32 (0)	2-12
Filamentation	Mod. MHD fast, slow		Nonclassical, nonlinear
13	15		2, 6

L.F. Electromagnetic, Electrostatic Waves
1, P1, P33

Many Two-Step Processes:

Hesse et al.	4	LHD → kink
Hurricane	2-14	
Lakhina	17	

Table 1, shows a number of suggested mechanisms such as ballooning mode, tearing mode, interchange instability, drift-kink instability, etc. Hesse et al. (3-4), Hurricane (2-14) and Lakhina (3-17) suggest two-step processes to accomplish substorm onsets.

What is very interesting, is that almost all of the papers at this Conference dealt with theoretical mechanisms/instabilities, but few have observational evidence of specific instabilities. The papers with an (O) have included observations. There are only two.

The existence of such a near-Earth neutral line is still under debate at this time. There are compelling theoretical and indirect observational arguments about why one should exist, but to date, there has not been any strong direct evidence. Part of the reason for the lack of concrete direct observations is that the plasmasheet is turbulent and therefore any specific evidence is difficult to identify. In addition, the x-line most likely does not remain fixed in space and also may be small in both GSM x-and-y extent. One

suggestion to make progress is that more effort should be put into searching for specific wave enhancements at the time of substorm onsets (in addition to the current intense theoretical efforts). This will benefit the field in two ways: 1) There may be other mechanisms /modes that have not been thought of previously, and detection of these (modes) will complement and stimulate theoretical work. 2) Another possibility is that such instabilities do not exist at all. But how can one go about searching for the existence/nonexistence of such waves/turbulence/plasma and field structures in a useful and efficient way?

Several important ideas have been presented at this meeting which, if used, could help identify and locate the reconnection process region. Paper 2-11 by C. I. Meng et al. (1998) has shown that the best identifier of substorm onsets is auroral brightening. Meng et al. used the Polar UVI data and a threshold of 1 kR of auroral brightness for onset identification. Clearly, other thresholds could be used since this number is an arbitrary one. For a survey of near-Earth X-line reconnection, one suggestion is that the substorm onset first be identified by a "marker" of this type. Auroral brightening was the definition used by Akasofu (1964) in his original paper defining substorms, so this is also consistent with the oldest definition as well.

Another ingenious idea was provided by Lui (paper 2-12). He looked at ion flows detected in the plasmasheet at the time of substorm onsets. The spacecraft was at different positions in the tail during different substorms, so a large area in space is mapped out. Thus, this "multispacecraft" approach (actually with only one or several spacecraft) can be used for a study of x-line signatures as well.

One should thus first identify hundreds of substorm onsets using UV imaging data. Whenever a spacecraft is in the plasmasheet at the time of the substorm onset, the magnetometer, plasma and plasma wave data should be examined for time T = 0 and times prior to T = 0, for up to 30 min prior. A movie could be generated that will show the wave/field/particle data for all 100 - 200 substorm onsets at the same time (as Lui has shown). One can therefore visualize where in the tail wave amplitudes/fields/plasma flows are particularly large and at what time this occurs relative to T = 0. This will help localize the region of instability and also indicate the time sequence of phenomena (several papers discussed a sequence of instabilities).

On the other hand it is also possible that no obvious waves are noted. This would be an indication that microscale processes are not important, and other processes control substorm onsets.

Conclusions

I have proposed a simple test of determining if waves are important in causing substorm onsets. I hope that there will be a person/group who will attempt this or some similar experiment in the near future to provide the community with an answer to this very important question.

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References

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